4GR 380

UGR File #380
CER Corp.
August 1978

Western Gas Sands Project

Core Program
Including Current Areas of Interest

FILE # 380

August 1978

Prepared for
U.S. Department of Energy
Bartlesville Energy Technology Center
Charles R. Atkinson
Project Manager

Compiled by CER Corporation
Las Vegas, Nevada

Contract EY-76-C-08-0655

Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

NATIONAL TECHNICAL INFORMATION SERVICE PAPER COPY PRICES
EFFECTIVE JAN 1,1976

Page range	Domestic price	Page range	Domestic price	Page range	Domestic price	Page range	Domestic price	Page range	Domestic price	Page range	Domestic price
001-025	$3.50	126-150	$6.00	251-275	$ 9.00	376-400	$10.75	501-525	$12.75	701- 800	$18.75
026-050	$4.00	151-175	$6.75	276-300	$ 9.25	401-425	$11.00	526-550	$13.00	801- 900	$21.25
051-075	$4.50	176-200	$7.50	301-325	$ 9.75	426-450	$11.75	551-575	$13.50	901-1000	$23.75
076-100	$5.00	201-225	$7.75	326-350	$10.00	451-475	$12.00	576-600	$13.75	1001-1100	$28.25
101-125	$5.50	226-250	$8.00	351-375	$10.50	476-500	$12.50	601-700	$16.25	1101-1200	$32.75

For additional pages, add $4.50 for each beginning 100 pages. Add $2.50 per copy for foreign price.

Microfiche $3.00 (domestic) $4.50 (foreign)

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

A vital part of the resource assessment and reservoir analysis work in evaluating the potential for gas production from the western basins is the coring program. In addition to the resource assessment, the program should prove valuable in the resource development by providing information needed for gas recovery estimates and well spacing as well as improving stimulation technology.

The USGS is doing the majority of the resource assessment work and has the lead role in identifying areas where cores are needed. To obtain the cores, associated well logs, test data, etc., in the areas of interest, the Department of Energy (DOE), or one of its contractors will negotiate cooperative agreements and/or contracts with interested companies. Special well tests and analyses using computer techniques also may be part of the total evaluation program. Figure l-l shows the event sequence for core aquisition planning.

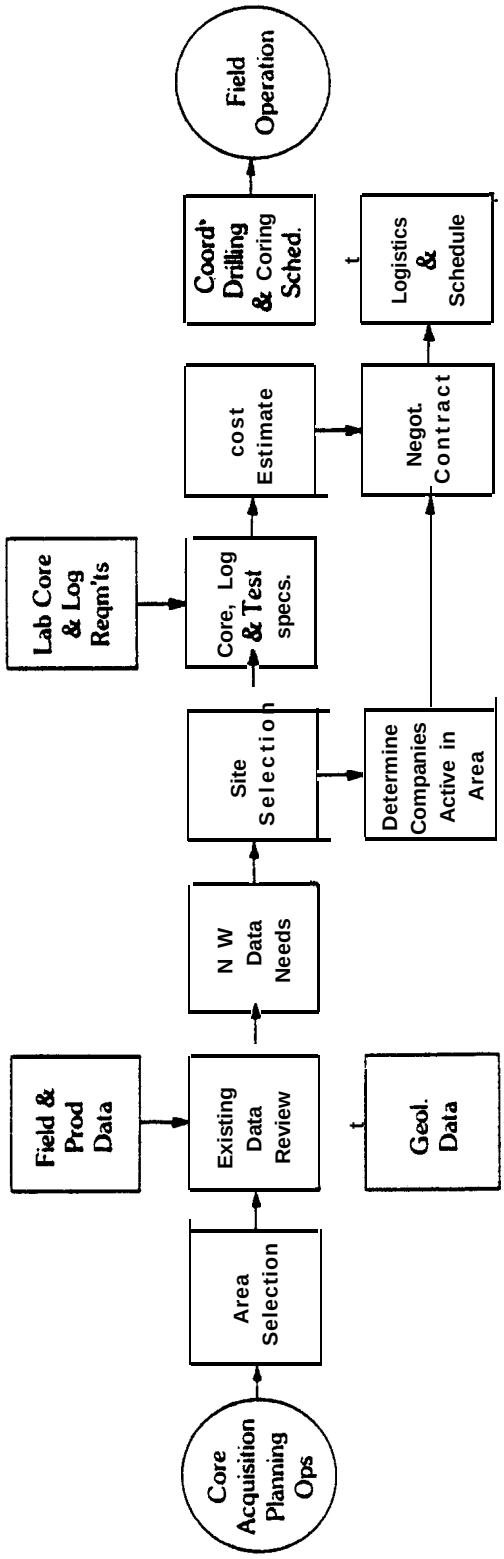

Figure I-I Event Sequence for WGSP Core Acquisition Planning

2. GENERAL

Drilling activity in the areas of interest will be closely monitored so that when applications for drilling permits are filed in areas where coring is desirable, contracts for the coring, logging, and possibly testing operations can be negotiated with the individual companies. The amount of core and any special core requirements of the various laboratories, USGS and other interested parties will require close coordination and detailed specifications early in the program so that maximum benefit and cost effectiveness can be achieved. Tentative priorities for core material disposition and analyses are given in Section 4.

3. FIELD OPERATIONS

When the coring, logging and testing requirements for each site have been specified and the cooperative agreement negotiated with the company, the operations schedule will be planned so that logistics for coring, logging and testing procedures can be coordinated with the drilling operation. When the drilling schedule is known for the well, the CER coring supervisor will make arrangements for the necessary coring materials to be on site prior to reaching the coring point. Figure 3-l shows the event sequence for field and laboratory core operations.

3.1 Field Personnel

The CER coring supervisor will be on site during the drilling operations to assist the operator in selecting the coring points and in supervising the core recovery, marking, reassembly, sampling, core description, recording, boxing and arranging for core shipment. Core handling requirements will be the coring supervisor's direct responsibility. Additional personnel will be on site as required, depending on the amount of core to be taken, and any special handling requirements.

3.2 Fieid Logistics

CER will provide core racks on site to accommodate the entire core after removal from the core barrel. The core rack will be located away from the rig floor so that core marking, sampling, packaging, etc., can be conducted without interfering with the drilling/coring operation. Extreme care needs to be exercised during the removal of the core from the core barrel and subsequent placement in the rack so that the core is oriented exactly as removed from the core barrel and scribed as discussed in Section 3.3.

Adequate lighting will be required for the core rack area so that the core handling operations can be carried out as soon as possible after the core has been recovered. A sheltered area is required for storage of the boxed cores until shipment and to provide protection for the coring supplies. Materials required for the coring operation are as follows:

1. Cardboard core boxes - usually 4" x 4" x 3'
2. Plastic bags or tubes, rubber bands and tape
3. Waterproof marking pens (black and red)
4. Rags
5. Staple gun and staples
6. Lithologic description sheets

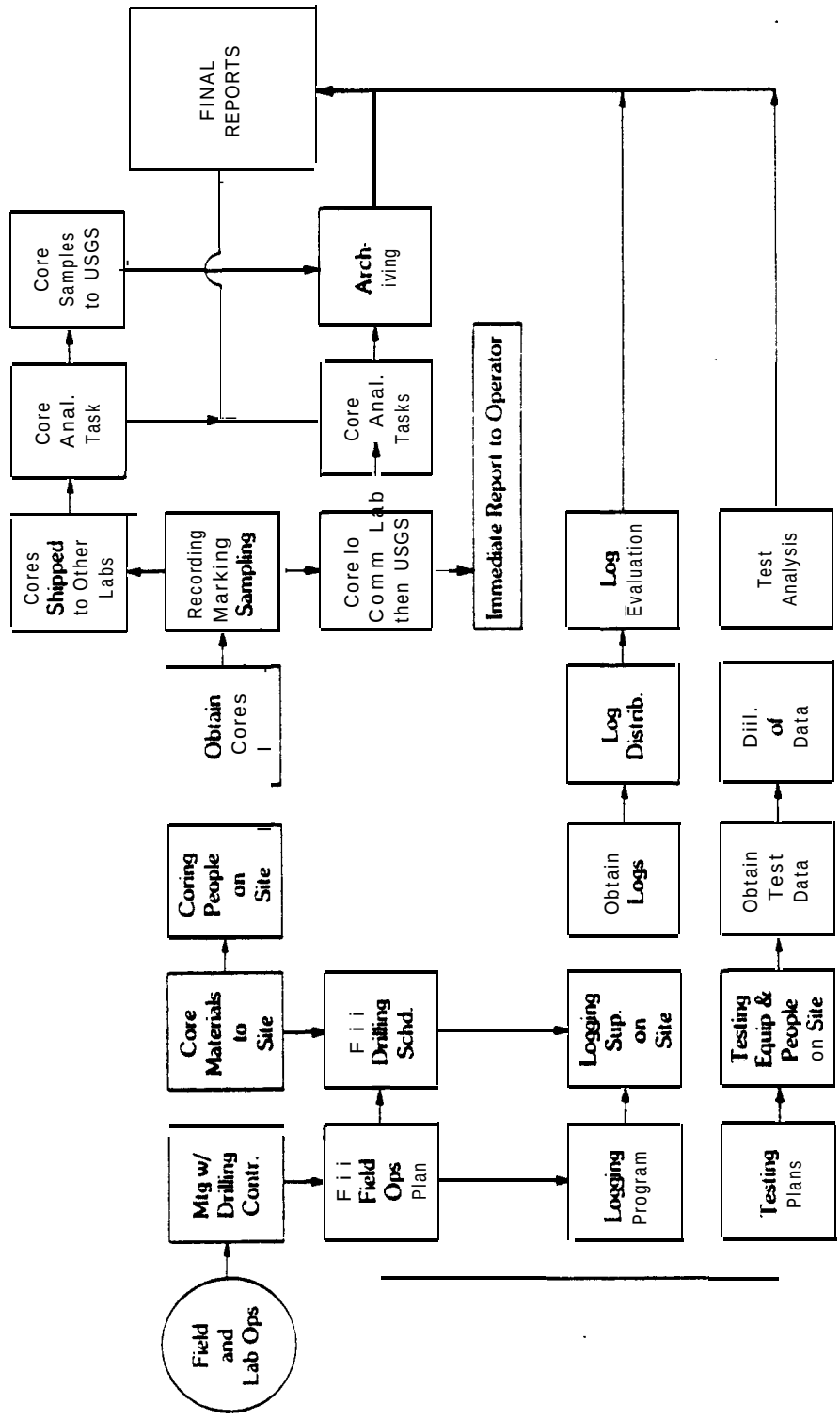

Figure 3-1 Event Sequence for WGSP Field and Laboratory Core Operations

7. Core carrying boxes (wooden or metal - marked "top" and "bottom") .

8. Rock hammer or chisel

9. Hand lens

10. Camera and stand

11. Wooden blocks for missing core sections

12. Other equipment as specified for special core handling; i.e., canning equipment for canned cores, small boxes for sending core samples to other laboratories, saran wrap and wax for sealing cores (if required), etc.

13. Bactericide, sample bottles for mud sampling, etc.

3.3 Core Recovery and Reassembly

The core should be placed on the core rack, wiped clean with a damp cloth, reassembled as accurately as possible; and marked with two vertical parallel lines using waterproof felt tip pens; one black and one red. Standing at the end of the core, the red line must be on the right, and the black on the left, looking at the "up" direction of the cores. For oriented core, the core should be lined up by the three orientation grooves on the core and marked accordingly.

The core should be fully identified for depth every foot and missing sections noted. The core should then be lithologically described, and photographed if required. Fracturing of the core should be noted on the core description including orientation of fracture, for example -- "Incline fracture of 55° from horizontal". The standard USGS lithologic symbols and abbreviations are found in Appendix I of this report and will be used in the core descriptions. As part of the record, the coring time by depth should be included with core descriptions. If samples of the drilling mud are desired, the drilling mud should be obtained from the flow line near the completion of the coring operation. The, drilling depth and date should be marked on the mud sample bottle. Bactericide should be added if the sample is to be stored.

3.4 Core Sampling and Recording

Specific core sample requirements may vary from area to area. However, the sampling and recording procedure will be conducted in a professional manner as a standard operating procedure.

After the core has been reassembled on the rack, marked and described, the core may then be sampled in accordance with the plan agreed upon by the participants. When a sample of the core is removed from the rack, a wooden block of the same length should be put in place of the sample. The depth of the core sample should be marked on the block along with the laboratory name that will receive that piece of core. This should also be noted in the core description.

3.5 Core Packaging and Shipping

The samples will be packaged and shipped as specified by the receiving laboratory.

After sampling and distribution of the core to the respective laboratories, the remaining core will be wrapped in plastic bags or tubes and placed in the core boxes, including the wooden spacers. The core boxes will be clearly marked with the following information: well name, location, box number, and core depth (interval).

In most cases the core will be shipped to a commercial laboratory for routine analysis' prior to delivery to the USGS Core Library.

The commercial laboratory will be responsible for delivering the core to the USGS. When cores are to be shipped direct to the USGS, the cores will be shipped motor freight at the less expensive "earth sample rate" to:

USGS *Core* Library
418 Orchard Street
Golden, Colorado 80401

The USGS will then handle the core as described in Section 4.

4. CORE LABORATORY OPERATIONS

Table 4-l indicates the tasks that may be performed by the laboratories. Specialized core analysis may also be performed by universities and commercial laboratories under contract to DOE.

4.1 U.S. Geological Survey (USGS)

The USGS will be the primary core storage facility. The USGS will provide personnel and facilities necessary for processing and storing the cored materials.

In addition to archiving the core, the USGS will perform the following specific laboratory studies on selected core samples:

1. Petrographic analysis including diagenetic and paragenetic histories of the reservoir rocks.

2. Micro paleontology studies will be made on cores from selected sites.

3. Pore geometry and size relations will be studied using SEM and thin section techniques.

4. Determine the effects of depth and temperature on porosity-permeability characteristics.

5. Geochemical analysis on selected shale, siltstones and coal for level of thermal maturation and organic richness.

6. Clay Mineralogy Studies

   a. Determine the mineral types, exchangeable cations, swelling characteristics, distribution and amounts of clay minerals present in tight gas sands and associated rocks. The samples will be analyzed by X-ray diffraction and fluoresence methods to determine presence , types and relative amounts of clay minerals. Wet chemical lab techniques will be used to determine the exchangeable cations present and the swelling characteristics.

   b. Determine the origin of these clays.

   c. Determine the relationships between specific types of clay and the occurrence of natural gas.

   d. Determine the character of the clays present in pore throats of tight sandstone reservoirs using scanning electron microscopy and electron probe techniques.

In addition to the actual core storage and laboratory work, USGS will assist DOE in selecting areas where core data is needed to assist in the assessment and characterization of natural gas resources in the low permeability reservoirs of the western United States.

4.2 Bartlesville Energy Technology Center (BETC)

BETC will work on Rw, surface area, proppant embedment studies, fluid flow permeability, porosity and miscellaneous optical and electron microscopic studies. In addition, BETC will contract with some universities to do special logging studies on core samples.

4.3 Lawrence Livermore Laboratory (LLL)

LLL will develop state equations which can be used for theoretical analysis. LLL will compare log measurements with the state equations for the core material and also compare the log measurements with the core material in both the pay and barren zones to improve the formation evaluation capabilities. Samples across lithologic boundaries will be studied for significant physical properties.

4.4 Sandia Laboratories

Sandia Laboratories has the capability to perform essentially all the tasks listed on Table 4-l. However, Sandia is not set up to perform these tasks on a routine basis. Sandia will maintain a high interest in the core data as they become available and especially in those that are related to Sandia programs in the Western Gas Sands Project. Specific areas where active Sandia participation in the core analysis may occur are:

1. Those properties measured under simulated in situ conditions, particularly where new techniques have to be developed to obtain important specific data.

2. Application of established capabilities in computer based log-property correlation techniques.

3. Correlation with various borehole formation measuring techniques under development in Sandia programs.

4. Fracture toughness measurements and interpretation.

5. Aiding in the detailed analysis in a region of specific interest.

Table 4-1 Core Tasks

TASKS	LABORATORIES						
	USGS	BETC	SANDIA	LLL	LASL	COMM. SERVICE LABS	CO'S
ρ_g Grain Density	0		0	0	1	2	1
Pb Bulk Density	0		0	0	1	1	1
ϕ Porosity	0	1	0	0	1	2	
Sw Saturation		1	0	0		2	
K Permeability	0	1	0	1	1	2	
K' In Situ Permeability		1	0	1	1	1	
A Surface Area		1	0	0	1		
SEM Scanning Electron Microscope	2	1	0	0	2		1
X-ray	2		0	0	0		1
Clay Mineralogy	2		0	0	0		1
Thin Sections	2			0	0		1
Petrography	2			0	0		
Log Correlations	2	1	1	1	1		
Log Parameters		1	1	1	1		
Surface Mechanical Properties		1	1	2	1		1
In Situ Mechanical Properties			1	2	1		
Proppant Embedment		1	0		0		1
Proppant Transport		1	1		0		1
Surface Frac/Fluid Formation Interaction		1	1		1		1
In Situ Fluid/Formation Interaction			1		1	1	
Stress Relaxation			0			1	
In Situ Stress			1	1	0		
Directional Properties			1	2			
Micro Paleo	2						
Org. Geochemistry	2						
Slab, Photograph and Archive	2						
Core Gamma Log						2	

CAPABILITY: (Level of Effort)
0 = None
1 = Minimum
2 = Routinely

4.5 Los Alamos Scientific Laboratory (LASL)

The LASL will investigate fluid and gas transport through selected core sections under conditions simulating in situ conditions. Permeability measurements will be made as a function of fluid saturation levels. SEM studies on specimen cores will explore the nature and extent of fluid interactions, including potential fracture fluids.

LASL will also study organic constituents in selected samples. Using standard extraction and pyrolysis techniques, the types and quantities of organic compounds in various lithotypes will be determined as well as interactions between hydrocarbons and core components.

4.6 Commercial Core Laboratories

Routine analysis will be run on the sandstone section of the core. As a normal operation, the core will be plugged every foot in the sand interval and routine porosity, grain density, permeability and saturation measurements made on the core plugs. A two foot unplugged section will be left in each 10 foot section of sand. A Core Gamma log will be run over the entire core sent to the commercial lab. At the completion of the routine analysis the core and plugs will be shipped to the USGS Core Library.

Commercial core l&oratories will be used to run the above routine analysis and occasionally to supplement the Energy Research Centers and National Laboratories' efforts to run special tests, like preferential fracture direction, core relaxation studies, etc.

4.7 Fracturing Service Companies

These companies will provide information on proppant embedment, fluid damage and fracturing properties of the core materials.

4.8 Specific Core Requirements

BETC

Core Analysis	6" x core dia every 10 ft.
Log Correlation	12" x core dia every 20 ft.
Plus Samples at abrupt interfaces	

LLL

Equations of state	12" x 4" dia - longer if broken up

Samples from selected sandstone and shale intervals and at sand/shale interface. Approximately 6 ft from each well and a maximum of 10 - 12 ft in a year.

· Sandia

Sandia will not require core unless they are requested to perform some special analysis.

LASL

Requests a maximum of 10 ft per year

Special handling may be required	2 ft pieces with approximately half sand and half shale is desired

USGS

Cation Exchange, X-ray, thin section, micropaleo, organic geochemistry	2" x 3" samples approximately every 10 ft or where needed
Sedimentary structure, etc. Archives	Complete slab or core approximately 1 in. thick

When work on core samples has been completed, the samples should be saved and returned to the USGS Core Library for storage with the remainder of the core. Even crushed and broken core can be used for SEM work, clay mineral analysis, etc. core sections that have been plugged can still be slabbed, photographed and archived.

5. LOGGING PROGRAM APPLICATION TO CORING

The logging program will include a comprehensive suite of geophysical well logs. The program will involve the use of commercial and experimental logs available from several service companies. In addition, experimental logging tools developed by the government and national laboratories may be run. The log suites are necessary to augment the development of the coring and testing program. One of the objectives of this study will be to correlate log-core-test data, and apply these relationships to other wells. A goal of this program is to develop accurate log interpretations so that other wells can be evaluated by use of logs only.

Logging programs will be carefully planned for each well on an individual basis. The criteria for log selection will include formation salinity, type of drilling mud, shaliness characteristics, lithology complexity, anticipated invasion profile, and past experience in the immediate area.

A typical log suite in the Western Gas Sands Project probably would include Rt, R_{xo}, Spontaneous Potential (SP), Gamma Ray, Sonic-Porosity, Neutron Porosity, and Gamma-Gamma Density. This logging should be sufficient to quantitatively determine resistivity, porosity, shaliness, water saturation, and movable hydrocarbons, and.to give a qualitative' indication of lithology and permeability. Dipmeters may be run to determine structure and possible faulting. In some of the tight areas of extreme shaliness, it may be desireable to run Neutron Lifetime- or Thermal Decay Time-type logs. All logs should be recorded at the well site on magnetic tape.

The DOE logging representative will be *on* location to assist the operator in monitoring the logging program and will be concerned with proper equipment calibration, adherence to acceptable logging speeds, validity of tool response, and notation of irregularities on log headings. CER will be responsible for the distribution of the logging data to the various laboratories, institutions, and parties involved in the interpretation and/or correlation of log data to core and test data.

Interpretation of the log data will include conventional computer analysis along with crossplot techniques to empirically relate quantitative formation parameters as determined from the relationship of well logs to the core and test data. Emphasis will be placed upon the mathematical relationship and the relationship of formation parameters to methods for economical well stimulation.

6. TESTING

In certain wells it may be desirable to obtain formation test data as well as logs and cores. Primarily, production and pressure buildup tests may be run to determine how reservoir and fluid properties compare with those determined from core and log measurements. The testing program will be designed for individual areas, and will be dependent on the completion program and the willingness of the operator to cooperate in running the test program.

7. DISTRIBUTION OF INFORMATION

CER will collect the data on core analysis, logging and testing (if any) and prepare a report for distribution to the participating organizations. CER will be contacting each laboratory that receives core to obtain the results of the laboratory work. While it is understood that some of the investigations will be taking place over a long period of time, periodic reports of the investigations will be required.

Copies of all logs and core analysis will be distributed as soon as available to the following:

ORGANIZATIONS	COPIES
BETC	1
USGS	1
Sandia	1
LLL	1
LASL	1
DOE NV	1
WE Hdqtrs.	1
CER	5 + Originals
OPERATOR (per request)	____
TOTAL	12 + Operator requirements

8. DESIGNATED CORE AREAS

8.1 Northern Great Plains Province

The USGS has delineated a large area of Montana, northeastern Wyoming, and western North and South Dakota as having tight gas potential. This area is called the Northern Great Plains Province and comprises an area of about 125,000 square miles (see Figure 8-l). The western boundary based on the cropping out of potentially productive Upper Cretaceous units or where these units have developed into porous and permeable shoreline sandstones. The northern boundary is on the Canadian border and the southern boundary is along the north end of the Powder River Basin. South of this boundary the units are too deep for significant biogenic gas accumulations. The eastern boundary is based on the eastern limit of tight clastic reservoirs in the Upper Cretaceous units. However, there are chalks in the Upper Cretaceous Niobrara, Carlile and Greenhorn units in the eastern part of the province. These chalks have high porosities but low permeabilities and are considered to have excellent shallow gas potential. The eastern boundary of the province probably will be extended well beyond the present location when the extent of the chalks becomes known.

The USGS has chosen four core sites in the Montana segment of this Province to evaluate the Upper Cretaceous section (see Figure 2-2). Specific formations in each site are included along with the approximate coring intervals needed to effectively evaluate each location.

1. Powder River County
   TSS, R52 and 53E
   Judith River 200 ft
   Eagle 400 ft
   Niobrara (chalk) 200 ft

2. Custer and Prairie Counties
   T10 and 11N, R48 and 49E
   Judith River 200 ft
   Eagle 400 ft

3. Valley County (fractured reservoir)
   T29N and 30N, R35, 36 and 37E
   Eagle through Upper Mowry 1,450 ft

4. Phillips County
   T29 and 30N, R26 and 27E
   Eagle through Upper Mowry 1,400 ft

These sites were evaluated by DOE contractors and modified or expanded to some degree. The dotted lines in Figure 2-2 represent the modifications. The outlined location immediately north of the USGS Site No. 1 was chosen primarily to take advantage of some Upper Cretaceous porous sands that might be of more immediate interest to industry.

Sites 1 and 2 were chosen to evaluate the Judith River, Eagle and Niobrara (Chalk) sections and Sites 3 and 4 offer evaluation of the Eagle through Mowry section. All the sites are outside the commercially productive area, have two or more potential reservoirs as well as adjacent source beds to test and there are fractured reservoirs along a lineamentzoge at Site 3.

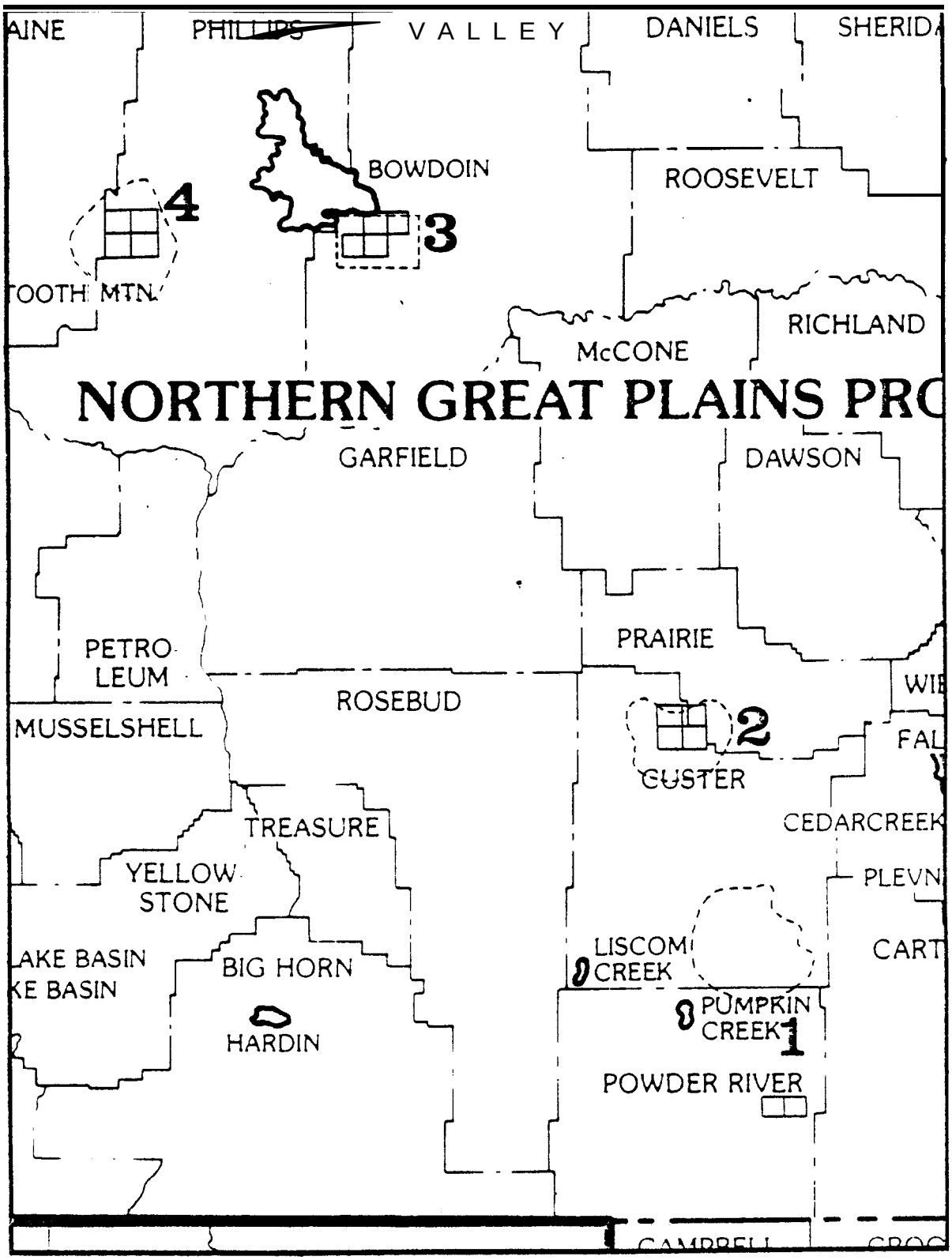

Figure 8-1 USGS Designated Core Areas, Northern Great Plains Province

8.2 Greater Green River Basin

There has been a significant amount of work accomplished by the USGS in the Greater Green River Basin of western Wyoming on "tight gas sands." The entire basin (see Figure 8-2) has a large amount of section with gas potential in the Upper Cretaceous and Tertiary rocks. However, based on current USGS evaluations, there are selected areas (listed below) that contain a large amount of tight, but essentially, untested section which should be the primary study areas in the.Greater Green River Basin for the Western Tight Gas Sands Core Program.

1. The crest of the Warnsutter Arch in Sweetwater and Carbon Counties, the northern edge of which borders on the Red Desert Basin and the southern edge occupies part of the Washakie Basin, T17N to T21N, and R91W to R26W. The section below the commercial Almond and Ericson (Mesaverde) is of primary interest in this area.

2. The area east of the Big Piney/LaBarge Field in Sweetwater and Sublette Counties, running north and south through the Pinedale area and to the northern edge of the Green River Basin: These areas skirt the edge of the Wind River Range. Production here is primarily Frontier, with some Mesaverde and Ff. Union tests.

   This large area'has been broken down into four areas. The specific locations are:

   a. West of R104W to R109W and from T22N, north to T28N

   b. R106W to R111W and from T27N to T31N

   c. R108W to R112W but not including development drilling, and T30N to T35N

   d. North edge of Green River Basin; north into the Hcback Basin, T36N to 39N and R112W to 114W.

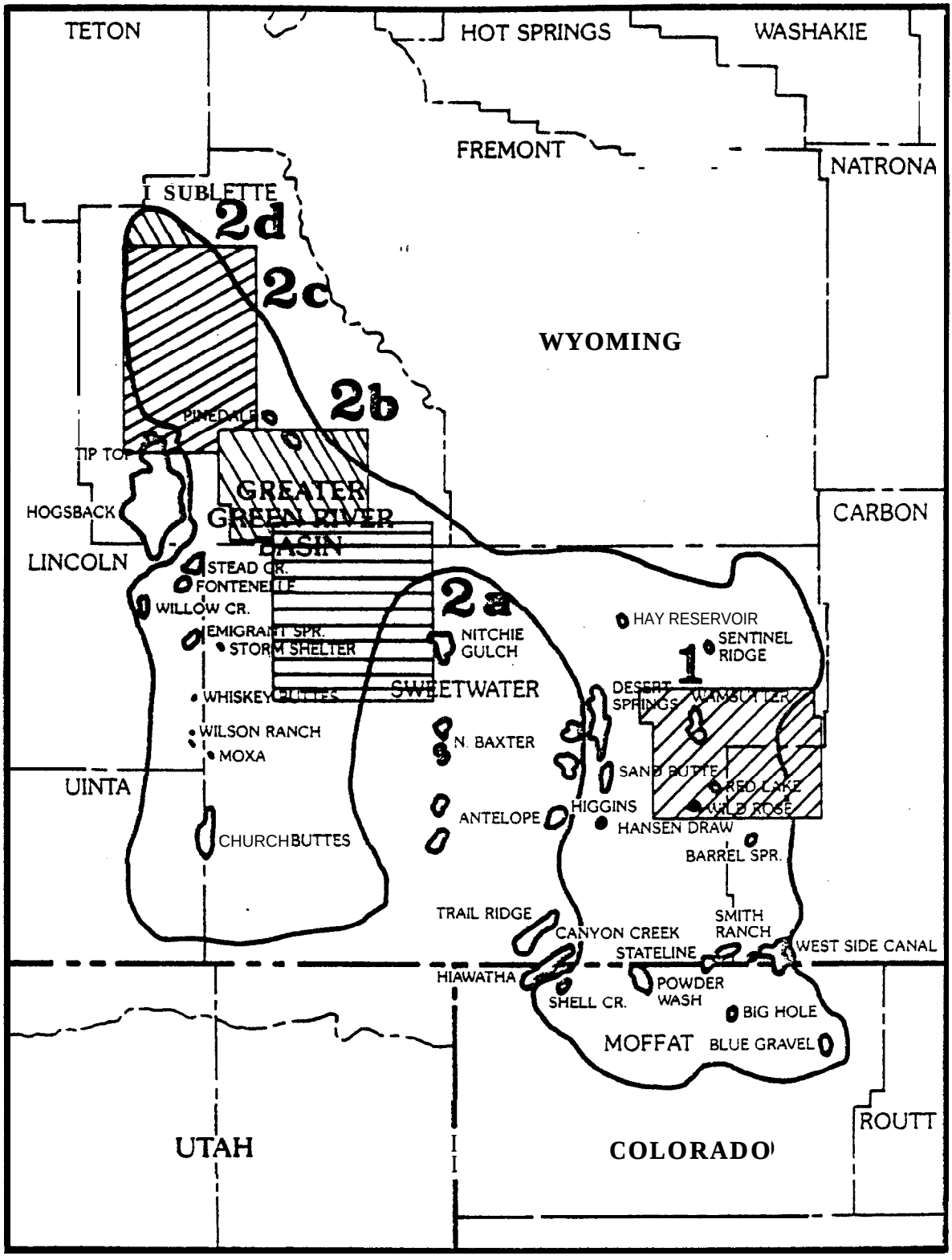

Figure 8-2 USGS Designated Core Areas, Greater Green River Basin

8.3 Uinta Basin

The boundaries of the Uinta Basin (see Figure 8-3) enclose a large area of northeastern Utah with potential "tight gas sand" production. The potentially productive rocks range in age from Upper Cretaceous to Tertiary. Examples of Cretaceous rocks are the Price River, Castlegate, Blackhawk, Sego, Neslen, and Farrer. The Tuscher, Wasatch, North Horn and the Green River are examples of Tertiary rocks. The USGS has recently outlined specific areas of this basin for the acquisition of core in the WGSP core program. These areas, listed below, have limited core data from the potentially productive sections of interest.

1. Wasatch and Duchesne Counties - T4S to T7S, R5W to R11W; in Wasatch County, T9S to T11S, R7, 9 and 9E; in Carbon County, T11S to T12S, R7E to R13E.

2. Duchesne and Uintah Counties - T3S to T4S, R2E to R2W and parts of T8S, R16E to R18E.

3. Uintah County - T8S and T9S and R23, 24 and 25E.

4. Uintah and Grand Counties - T10S, R18E; T11S to T16S, R18E to R25E; and in T17S, T18S, and T19S, R21E and R22E.

These areas are outside the productive fields of the Uinta Basin.

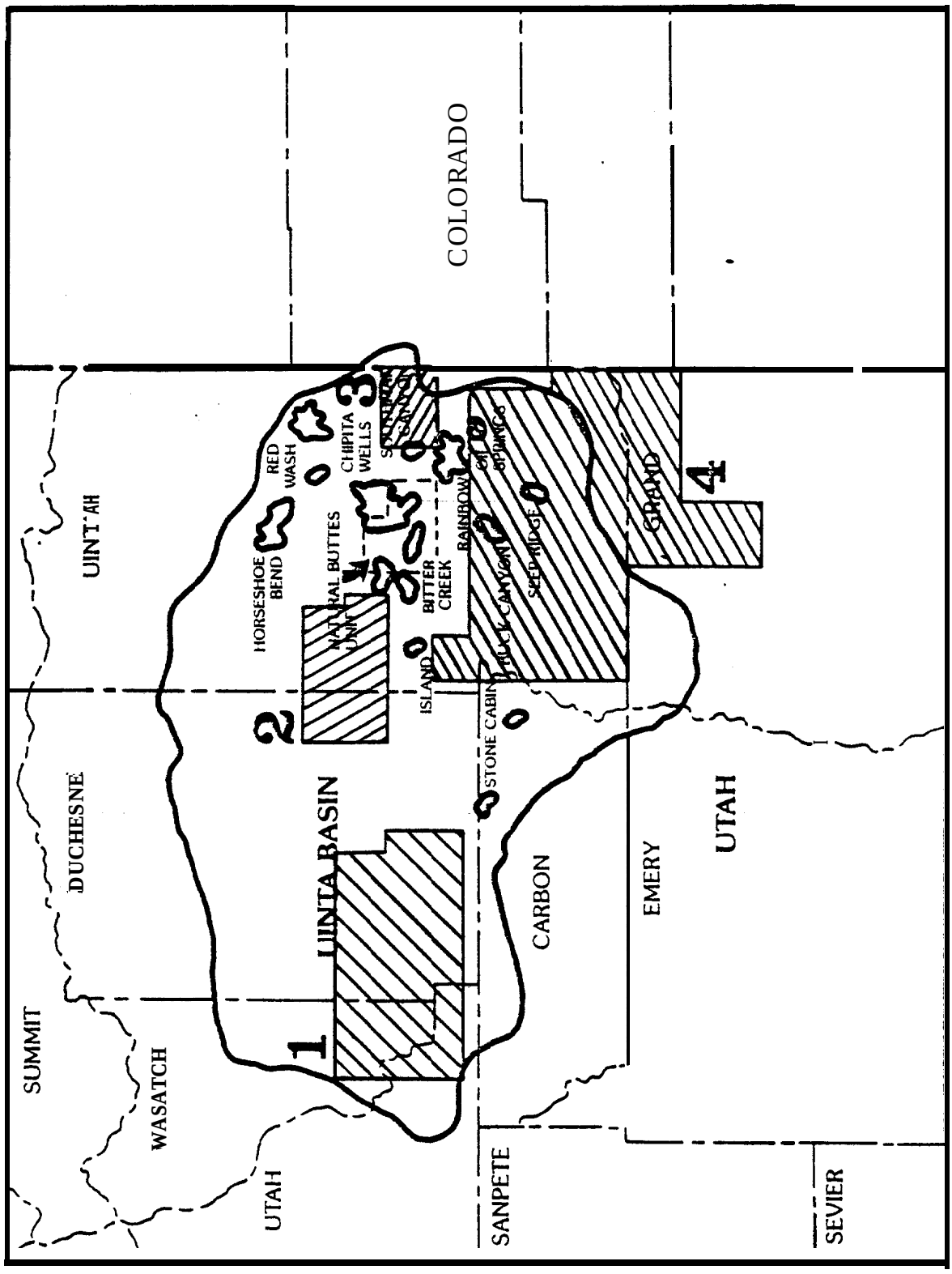

Figure 8-3 USGS Designated Core Areas, Uinta Basin

8.4 Piceance Basin

The Piceance Basin of northwestern Colorado (see Figure 8-4) has a large amount of tight Upper Cretaceous and Tertiary gas sands, such as Castlegate, Sego, Corcoran, Cozzette, Iles, Williams Fork, Ft. Union and Wasatch Formations. Some of these units are producing gas in very active fields such as Cathedral, Piceance Creek, Trail Canyon, Thunder, Dragon Trail and Texas Mountain. However, outside of these fields, very little information is available on these units due to a limited amount of drilling activity. For instance, in the Piceance Creek Field, there is also interest in, but little data on, rocks below the commercial Wasatch. This becomes even more evident when attempting to find suitable core data for these rocks. The USGS has indicated key areas in the Piceance Basin with a significant amount of "tight gas" sections but limited control. These areas will be used initially to acquire the needed information specified by the WGSP Core Program. The following is a list of these areas:

1. East of Rangely Field in Rio Blanco County, T1S to T2N, R98W to R99W.

2. Piceance Creek Field area, Rio Blanco County, T2S, R96W to R97W.

3. Garfield and Mesa Counties, T5S to T8S, R95W to R99W in the north tapering down to R96W to R99W on the southern part of the area.

4. Garfield and Mesa Counties, T8S to T10S, R92W to R94W (this area is flanked on the northwest and southeast by the Grand Mesa National Forest).

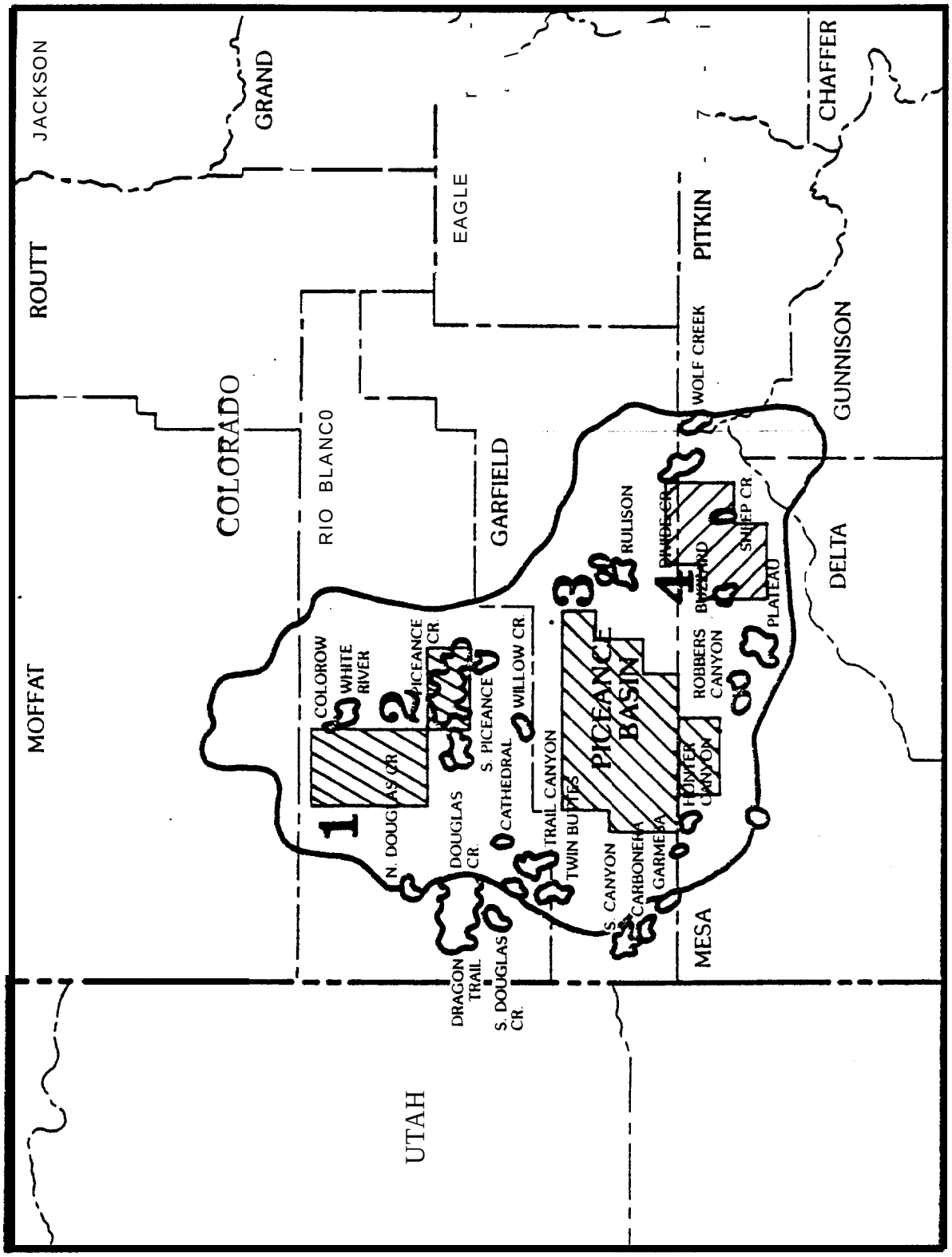

Figure 8-4 USGS Designated Core Areas, Piceance Basin